(1940s)

Meteorology Chapter 1-4 Cheat Sheet by chanhmuoi via cheatography.com/198300/cs/41938/

Chapter 1

Scientific Method

- Make observations
- Make a hypothesis
- Has to be tested
- Make prediction assuming hypothesis is true
- Carry out experiments
- Mathematics is the tool to understand and predict the natural world
- Scientific Method and Meteorology
- Atmosphere obeys laws of physics and chemistry - Instruments allow us to
- quantify the state of the
- atmosphere
- Thermometer
- Hygrometer
- How much humidity/moisture in air
- Barometer
- Air pressure
- Anemometer
- Wind speed/wind direction
- Mathematics can project
- current conditions into the future - Uses computer models to help
- with calculating
- Weather and Climate - Weather describes state of the
- atmosphere at any given time
- Temperature
- Air Pressure
- Humidity
- Cloud Cover
- Precipitation
- Visibility
- WInd Velocity



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Chapter 1 (cont)	Chapter 1 (cont)
- Climate describes average	- These radiosondes provide 3D
atmospheric conditions over at	view of the atmosphere
least 30 years	- Numerical Weather Prediction
- Includes extremes	(NWP)
- The frequency of extremes	- Solving the mathematical laws
help differentiate between	of physics/chemistry at high
locations with similar averages	speeds
Meteorology	Remote Sensing of the
- Meteorologica	Atmosphere
- Book on natural philosophy by	- Weather Radar (1940s)
Aristotle in 340 BC	- Detects precipitation targets
- How meteorology got its name	from over 100 miles away
- Study of the atmosphere and	- Doppler Weather Radar
its phenomena	(1990s)
- Began with the invention of	- Detects precipitation targets
weather instruments (1450	and their motion
1650)	- "Sees" the wind
- Quantified the atmosphere	- Dual Pole Doppler Weather
- Allows for the prediction of	Radar (2000s)
what the atmosphere will do	- Distinguishes between rain,
- Telegraph (1843)	snow, hail, and bugs
- Allowed for the transmission of	- Weather Satellites (1960s)
current weather conditions	- Reveal weather features
across vast areas	produced by cloud patterns
- Weather Map Analyses (1869)	- Can supply NWP with data
- Visual snapshot of current	from every location on Earth
state of the atmosphere	- Most Common Type of
- Understanding of Air Masses	Satellite
adn fronts (1920)	- Geostationary
- Key weather features that drive	- Orbits the Earth at the same
world weather patterns	speed the Earth spins
- Daily weather ballon launches	- GOES 16 and 17 Satellites
(1040a)	Reat View of the US

- Best View of the US

Chapter 1 (cont)

- Centered over the Equator (0° Latitude) and 75° W | 137°W Longitude
- 22.300 Miles
- Latitude
- the angle made between center of Earth and a point on surface using the Equator as the reference line
- North Pole = 90° N Latitude | South Pole = 90°S Latitude
- Most of the US is between 30°N and 50°N Latitude

Longitude

- the angle made between center of Earth and a point on surface using the Prime
- Meridian as the reference line - Runs from N Pole to S Pole
- through Greenwich, England
- Most of the US lies between
- 70°W and 125°W Longitude
- Most Common Type of Storm System
- Middle-Latitude Cyclonic Storm System
- Extratropical Cyclone
- Cyclone=area of low pressure
- Anticyclones=are of high pressure

Depiction of Winds

- Wind is defined from the direction it is blowing

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Chapter 1 (cont)	Chapter 1 (cont)	Chapter 1 (cont)	Chapter 1 (cont)
- Represented by a line - wind	- Warm front	- Rapid pressure falls/rising	- It has to fulfill one condition to
barb - drawn parallel to wind	- Boundary that separates colder	humidity	be considered
- Points in direction from which	air from warmer air	- Can induce expansion of joints	- Flash Flooding
the wind is blowing	- When warmer air advances	and cause joint pain	- Slow-moving thunderstorms
- Speed is represented by wind	and replaces colder air	- Wind flowing downhill heats up	- "Training" storms
flags	- Occluded front	- Chinook winds/ Santa Ana	- Downburst winds
- Full flag = 10 knots	- When cold front merges with	- Incidence of depression	- Macroburst- greater than 4 km
- Half flag = 5 knots	warm front	increases	(2.5 mi) in diameter
Wind Flow	- All fronts are usually but not	Economical Impacts of Weather	- Microburst - less than 4 km in
- Counterclockwise and inward	always associated with rising	- Warm winters = lower heating	diameter
around lows	air, clouds, and precipitation	bills	- Both produce Wind Shear
- Clockwise and outward around	Impacts of Weather and Climate	- Beware of unusual winter	- Change in wind speed/dir-
highs	- Weather dictates the clothes	severe weather outbreaks	ection over short distance
In Southern hemisphere	we wear on any given day	- Cold winters = higher heating	Who Studies This?
- Clockwise/inward around lows	- Climate dictates the clothes we	bills	- Meteorologist
- Counterclockwise/outward	have in our wardrobe	- Severe Artic air cold snaps can	- Professionaly trained, college
around highs	- Climate dictates the type of	threaten human lives/infrastru-	degree in atmospheric science
- Wind does not cycle around the	crops we can grow	cture damage/massive crop	- Weathercaster
equator	- Weather dictates whether the	losses	- Good communicator of
- No hurricanes but tornados can	crops can be harvested	- Heat Waves and Drought	weather information
still happen	When Weather is Not What it	- Crops losses	Weather Business is Expanding
Vertical Wind Flow Around High	Seems	- Wildfires increase	- Private Meteorological
and Lows	- Wind Chill	- #1 in weather-related fatalities	- App Development
- Air converges and rises in the	- Body perceives a lower	Climate Change Bringing More	- Forensic services
center of low pressure (cyclone)	temperature than it really is	Extremes	Fundamentals of Meteorology
- Clouds/precipitation	- Hypothermia	- Heat waves and drought	The atmosphere is a mixture of
- Air diverges and sinks in the	- Frostbite	increasing	gases
center of high pressure (antic-	- Heat Index	- Flooding events increasing	- Nitrogen
yclone)	- Body perceives a higher	- Hurricane intensity increasing	- Oxygen
- Clear skies	temperature than it really is	Other Weather Hazards	- Argon
Weather Fronts	- Hyperthermia	- Severe Thunderstorms	- Water Vapor (highly variable)
- Cold front	- Heat Exhaustion or Heatstroke	- 50 knot (58 mph) winds	- Carbon Dioxide (generally
- Boundary that separates colder	Other Biological Impacts	- 1-in hail	increasing)
air from warmer air		- Tornado	

- When colder air advances and replaces warmer air



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Chapter 1 (cont)

rocks

noes)

dases

reappear

today

Water Vapor

turns to gas

Characteristics

Earth

- Greenhouse Gas

- Always invisible

- O2 is highly reactive/combines

with other elements to form

- O2 levels drop worldwide

Life Gets a Second Chance

-- Outgassing increases water

vapor/carbon dioxide (volca-

- H2O and CO2 are warming

- Takes over a billion years for

new photosynthesizing life to

- After another 1/2 billion years,

O2 levels are where they are

- 0% to 4% of the atmosphere

- Become visible when vapor

molecules "jump" on each other

to form droplets or ice crystals

- Condensation form droplets

- Deposition form ice crystals

- Evaporation is when liquid

- Water is only substance that

normal temperature/pressure

- Very effective at absorbing

outgoing radiation emitted by

can exist in all 3 phases at

Chapter 1 (cont)

Most of the gases are near the surface

- Air gets "thinner" as you go up 99% of atmosphere is within 19 mi of teh surface

- Blocks deadly solar radiation from reaching the surface

The First Atmosphere

- 4.6 BYA the atmosphere was mostly hydrogen and helium

- Some methane and ammonia thrown in

- Hydrogen and helium escaped into space

- Earth's gravity not strong enough

The Second Atmosphere

- Outgassing from Earth's hot interior (volcanoes)

- Mostly water vapor (80%), carbon dioxide (10%), and some nitrogen

- Water vapor "condensed" into clouds with rain lasting 1000s of vears

- Combined with asteroid/comet collisions that formed the oceans Water Vapor Levels in

- Atmosphere Drop
- Most of the water vapor converted to liquid water

- Atmosphere now just a few % water vapor

CO2 Levels Drop

- CO2 readily dissolves in water

Chapter 1 (cont)

- Combined with chemicals in the ocean to form limestone N2 Levels Increase
- Nitrogen is not very chemically reactive
- Once in the atmosphere, tends to stay
- 02
- Solar radiation splits water

vapor into hydrogen and oxygen - Hydrogen escaped into space

- Oxygen left behind
- 2.4 BYA, something wonderful happens
- Cyanobacteria (blue-green algae) produce O2 from photos-

ynthesis

- Earth begins to cool
- O2 combines with O to form O3 (ozone)
- O3 in upper atmosphere absorbs incoming radiation
- cooling the Earth - Methane breaks down in the
- presence of O2
- Warming effect of methane weakens
- Earth becomes very cold
- Cyanobacteria proliferate around the world removing CO2
- from atmosphere - Warming effect of carbon

dioxide weakens

- First Mass Extinction
- Earth gets covered in ice - Frigid Earth no longer supporting life
- No O2 being produced

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Chapter 1 (cont)

- Re-emits some of this energy back keeping the Earth warmer Carbon Dioxide
- Greenhouse Gas
- Comes from the decay of vegetation
- Volcanic eruptions
- Burning of coal, oil, natural gas (fossil fuels)
- Removed by photosynthesis of land and ocean plants
- CO2 gets stored in roots,
- branches, and leaves
- Chemical weathering of rocks
- CO2 dissolves in rainwater
- Forms carbonic acid
- Combines with minerals in rocks and becomes part of the rock
- Dissolves in Ocean water
- Used by sea critters to make shells
- Eventually sinks to bottom of the sea

Vertical Structure of the Atmosphere

Air is compressible

- Gravity pulls most -but not all-
- air molecules near the surface
- Air Density = # of air molecules in a given volume
- Mass/volume
- Air Density and Air Pressure

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Chapter 1 (cont)

- Force exerted by air molecules against a surface
- Same thing as the weight of
- the air above you
- At sea level, air weighs 14.7 lbs per square inch

Measuring Air Pressure

- 14.7 lbs/in2
- 1013.25 millibars (mb)
- 29.92 in Hg

Atmosphere is Very Thin

- Half of the air molecules is

- below 5.5 km (18,000 ft) - 99.9% is below 50 km (160,000
- ft)

Layers of the Atmosphere

 Atmospheric layers are defined by how the temperature changes with height

- Lapse Rate= rate at which temperature decreases with height

- In lower atmosphere, lapse rate = 6.5°C per km (3.6°F per 1000

- ft)
- Temperature can INCREASE with height
- This is called temperature inversion
- Lapse rate is negative
- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Ionosphere
- Lower part of the Thermo-

sphere



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Chapter 1 (cont)

- Solar energy strips electrons from N2 and O2 causing them to glow

Northern and Southern Lights

- Aurora Borealis N. Lights
- Aurora Australis S. Lights

Chapter 2

- Energy

- The ability to do "work": when an object moves
- Kinetic Energy
- Energy of motion- translati-
- onal, rotational and vibrational
- Potential Energy
- Energy that can convert to kinetic energy
- Water that is behind a dam
- Object suspended in the sky
- Temperature
- Average kinetic energy of atoms in a substance
- Some move fast, others not so
- Average motion = temperature
 When molecules move, rotate, and/or vibrate, we say that the
- object has a temperature - When air molecules move
- slowly, they crowd together - It is cold and air is dense

Chapter 2 (cont)

- When air molecules move quickly, they spread out
- We say it is warm and the air is less dense
- Internal Energy (Heat energy)
- The total kinetic and potential energy of all atoms or molecules
 Heat
- Heat is the transfer of energy from warmer objects to cooler ones
- The bigger the temperature difference, the faster the energy transfer
- Know how to convert temperature scales
- ## Temperature Measurements
- Important Temperature ValuesIce point
- Ice melts, water freezes
- 32°F, 0°C, 273.15K
- Steam point
- Water boils
- 212°F, 100°C, 373.15 K ## Types of Heat Energy
- Sensible Heat
- Heat energy that can be absorbed or released by a substance that results in a change of temperature
- Latent Heat

Chapter 2 (cont)

- Heat energy that is absorbed or released by a substance when the substance undergoes a phase change
- Temperature of substance does not change
- Let ice at 32°F absorb heat energy
- Ice melts, but its temp remains at $32^{\circ}F$
- Only after the ice completely melts will the water warm up
- If water freezes, it releases the same heat it took to cause it to melt in the first place but water temp does not change
- The surrounding air does warm
- How does heat energy get
- transferred?
- Conduction
- Heat transfer by contact of one substance with another
- Energy gets transferred from one molecule to the next
- Some materials transfer heat better than others
- Metals are good conductors
- Fiberglass, cork, wood, cloth,
- glass, water are poor conductors
- Air is a poor conductor of heat
- Heat (Thermal) Conductivity

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- Measure of how well a substance transfers heat energy #Why Temperature Decreases with Height - mm=nanometer= billionth of a um=micrometer or micron= - Sun des not heat air directly - Amr=nanometer= billionth of a meter- Amrax = 2897/T (answer is in µm)- Longwave is greater than 1.4 µm- Amosphere is mostly transparent to incoming sunlight - Amresnometer= billionth of a meter millionth of a meter- Amrosphere and be heated by - Air is mostly transparent to undoing of a meter- Amrosphere and be heated by enducing a diation for a meter- Am object that is a perfect absorber and perfect emitter of absorber and perfect emitter of - All objects above Absolute Zero radiate (emit) energy at - All objects above Absolute Zero radiate (emit) energy at - All objects above Absolute - All objects above Absolute - All objects above Absolute - An object that is a perfect - Absorption and Emission - Carowetion- Carowa absorbes and perfect emitter of - Some gases absorb Earth's - Absorption and Emission - Carbon Dioxide- Heat transferred? - Convection - vertical air motorns, also called thermals - Adveright transfer. - Much more efficient than - Convection - vertical air motorns, also called thermals - Advered thermals - Adversion - verti	Chapter 2 (cont)	Chapter 2 (cont)	Chapter 2 (cont)	Chapter 2 (cont)
## Why Temperature Decreaseswavelength- T must be expressed in Kelvin- Some will eat both or neither• Atmosphere is mostly 'trans- parent' to incoming sulpting- nm=nanometer= billionth of a meter- Stefan-Boltzmann and Wien's Law- Some will eat both or neither• Atmosphere can be heated by conduction- Facts- Ohly valid if object is a blackbody object- Arn object that is a perfect adiation- Jar is nostly transparent to outgoing terrestrial radiation- Atmosphere can be heated by conduction- Facts- An object that is a perfect adiation at then absorber and perfect emitter of radiation- Some gases absorb Earth's outgoing terrestrial radiation- Heat energy does not get readiated- All objects above Absolute Zero radiate (emit) energy at outgoing transfered?- All object sabove Absolute Zero radiate (emit) energy at outgoing transfered?- All caylengths outgoing transfered?- Some gases absorb Earth's outgoing transfered- Heat energy does not get ransfered?- OK = -273.15°C - 459.67°F or for and perfautre is between 2.7K and 6K- Absorption and Emission of energy emitted from every wavelength- Valer Vapor- Convection- Total Radiation emitted = Sum of energy emitted from every wavelength- Total Radiation emitted = Sum of energy emitted from every square meter of an object is given by the Stefan-Boltzmann aconduction- If absorption is less than emission, object cools down object stemperature remains the same- Akerage temperature of the Cas amolecules are picky about object stemperature remains the same- Akerage temperature of the cas absorb	- Measure of how well a	- Energy is carried by photon	- λ _max = 2897/T (answer is in	- Longwave is greater than 1.4
with Height- nm=nanometer= billionth of a meterStafan-Boltzmann and Wien's- Air is mostly transparent to incoming soulight- Atmosphere is mostly 'trans- parent' to incoming soulight- µm=micrometer or micron= millionth of a meter- Only vaili if object is a- Air is not transparent to uotgoing trenstrial radiation- Atmosphere can be heated by## Radiation Laws- An object that is a perfect absorber and perfect emitter of absorber and perfect mitter of absorber and perfect absorber absorber and perfect mitter of absorber- Air is nost transparent to absorber absorber <td>substance transfers heat energy</td> <td>particles defined by their</td> <td>μm)</td> <td>μm</td>	substance transfers heat energy	particles defined by their	μm)	μm
- Atmosphere is mostly "transparent" to incoming sunlightmeterLawincoming solar radiation- Sund does not heat air directly- µm=micrometer or micron=- Only valid if object is a- Air is not transparent to- Atmosphere can be heated by## Radiation Laws- An object that is a perfect- Some gases absorb Earth's- Ground absorbs sunlight- All objects above Absolute- Absorber and perfect emitter of- Some gases absorb Earth's- Atir is contact with ground gets- All objects above Absolute- Absorber and perfect emitter of- Some gases absorb Earth's- Heat energy does not get- OK = -273.15°C = -459.67°F- Absorbs all radiation thatsurface- Convection outcet to higher altitudes- Even in interstellar space, the- Absorption and Emission- Carbon Dioxide- Transferred?- Total Radiation emitted = Sum- If a boject absorbs radiation, it- Microus Oxide- Transferred?- Total Radiation emitted = Sum- If absorption is greater than- Ozone- Much more efficient thangiven by the Stefan-Boltzmann- If absorption is less thanEffect- Onvection - vertical air- Watts=Joules per second, J/s- Absorption- Average temperature of the- Advecton - horizontal air- Watts=Joules per second, J/s- Absorption- Radiation Quesens tha- Convection - vertical air- Watts=Joules per second, J/s- Absorption- Radiation Quesens tha- Advecton - horizontal air- Watts=Joules per second, J/s- Absorption- Radiation Quesens tha- Radiation (Eactrom	## Why Temperature Decreases	wavelength	- T must be expressed in Kelvin	- Some will eat both or neither
parent' to incoming sunlight- µm=micrometer or micron= millionth of a meter- Only valid if object is a blackbody object- Air is not transparent to outgoing terrestrial radiation- Sum observe can be heated by 	with Height	- nm=nanometer= billionth of a	- Stefan-Boltzmann and Wien's	- Air is mostly transparent to
Sun does not heat air directlymillionth of a meterblackbody objectoutgoing terrestrial radiation- Atmosphere can be heated by## Radiation Laws- An object that is a perfect absorber and perfect emitter of radiation- Some gases absorb Earth's outgoing radiation and then readiation- Ground absorbs sunlight- All objects above Absolute- Absorbs all radiation that surface- Some gases absorb Earth's outgoing radiation and then readiation- Air in contact with ground gets heated- All objects above Absolute- Absorbs all radiation that surface- Water Vapor- Ade energy does not get conducted to higher altitudes- OK = -273.15°C = -459.67°F ever wellpossible radiation- Water Vapor- Methane- Even in interstellar space, the ever well- Absorption and Emission- Carbon Dioxide## How Does Heat Energy Get ransferred?- Total Radiation emitted = Sum of energy emitted from every wavelength- If absorption is greater than emission, object cols down- Neitrous Oxide- Convection- Total Energy emitted by every square meter of an object is square meter of an object is square meter. Wim2 or W m^-22- If absorption = emission, object cols down- Average temperature of the same- Moving heat energy vertically and horizontally- Exe x 14 (results is in Watts per square meter. Wim2 or W m^-22- Absorption- Matmosphere?- Convection - vertical air motions- Watts=Joules per second, J/s- Absorption- Atmosphere?- Convection - vertical air motions- Selective Absorbers- Atmosphere? <td>- Atmosphere is mostly "trans-</td> <td>meter</td> <td>Law</td> <td>incoming solar radiation</td>	- Atmosphere is mostly "trans-	meter	Law	incoming solar radiation
- Atmosphere can be heated by conduction## Radiation Laws - Facts- An object that is a perfect absorber and perfect emitter of redition- Some gases absorb Earth's outgoing radiation and then reemit some of it back to the surface- Arround absorbs sunlight - Air in contact with ground gets heated- All objects above Absolute Zero radiate (emit) energy at - All vavelengths - Some vill only eat long wery well- All objects above Absolute redition- Some gases absorb Earth's outgoing radiation and then reemit some of it back to the surface- Heat energy does not get conducted to higher altitudes wery well- OK = -273.15°C= -459.67°F - Even in interstellar space, the to my and SK- Absorbs all radiation that els emit radiation- Water Vapor - Carbon Dioxide- Convection - Convection- Total Radiation emitted = Sum of energy emitted from every wavelength- If absorption is greater than emission, object cools down - If absorption = emission, object's temperature remains the same- Nareage temperature of the - Sorne gases, it would be 0°F- Much more efficient than conduction- Watts=Joules per second, J/s- Absorption- Radiation What Else Happens to same- Moving heat energy vertically - Advection - vertical air motions, also called thermals - Advection - horizontal ir in a vacuum- Watts=Joules per second, J/s- Absorption- Radiation (Electromagnetic na vacuum- Os constant variable - o is constant variable- Some will only eat shortwave radiation- Radiation threat tim - Radiation theracting- Canals transfer heat in air or water- Hot object se	parent" to incoming sunlight	- µm=micrometer or micron=	- Only valid if object is a	- Air is not transparent to
conduction- Factsabsorber and perfect emitter of radiationoutgoing radiation and then reemit some of it back to the surface- Ain objects above Absolute- All objects above Absolute- Absorbs all radiation thatsurface- Air in contact with ground gets heated- Carbon 1 (wear Vapor emitted for gene absorber and gene emitted for gene absorber and gene very well- OK = -273.15°C = -459.67°F emitted for gene absorber adiation- Water Vapor emitted for gene absorber adiation- Heat energy does not get conducted to higher altitudes very well- OK = -273.15°C = -459.67°F emitted from every- Absorb all radiation that must also omit radiation- Carbon Dioxide- Transferred?- Total Radiation emitted = Sum of energy emitted from every- If absorption is greater than emission, object cools down- Nitrous Oxide- Convectionof energy emitted from every square meter of an object is given by the Stefan-Boltzmann conduction- If absorption is less than sameEffect- Moving heat energy vertically and horizontally- E=o x T 4 (results is in Watts per square meter. Mim2 or W m^-2- Absorption- Absorption- Advection - horizontal air motions, also called thermals- Umittes is in Watts per square meter. Mim2 or W m^-2- Absorption- Transmission- Advection - horizontal air motions, also called thermals- Ois constant variable- Absorption- Radiation Wenn it Enters the Admiter theres the Addiation (Electromagnetic than cooler objects- Absorption- Transmission- Radiation (Electromagnetic na vacum- ois constant	- Sun does not heat air directly	millionth of a meter	blackbody object	outgoing terrestrial radiation
- Ground absorbs sunlight- All objects above Absoluteradiationreamit some of it back to the- Air in contact with ground getsZero radiate (emit) energy at- Absorbs all radiation thatsurface- heatedALL wavelengths- Absorbs all radiation thatsurface- Heat energy does not get- OK = -273.15°C= -459.67°Fpossible radiation- Water Vapor- conducted to higher altitudes- Even in interstellar space, the- Absorption and Emission- Carbon Dioxide- wery welltemperature is between 2.7K- If an object absorbs radiation, it- Methane### How Does Heat Energy Getand 5Kmust also emit radiation- Nitrous OxideTransferred?- Total Radiation emitted = Sum- If absorption is greater than- Ozone- Convectionof energy emitted from everyemission, object cools down- Average temperature of the Greenhouse- Much more efficient thangiven by the Stefan-Boltzmann- If absorption is less thanEffect- Moving heat energy vertically- Ero x T 4 (results is in Watts per- Radiative Equilibrium Temper-## What Else Happens to- Advection - horizontal air- Temperature has to be inwhich type of radiation they will- Transmission- Advection - horizontal air- Temperature has to be inwhich type of radiation they will- Radiation passing through air- Advactum- o is constant variable- Selective Absorbers- About 55% of incoming solar- Adiation (Electromagnetic- o is constant variable- Selective Absorbers- About 55	- Atmosphere can be heated by	## Radiation Laws	- An object that is a perfect	- Some gases absorb Earth's
- Air in contact with ground gets heatedZero radiate (emit) energy at ALL wavelengths- Absorbs all radiation that strikes it and then emits maxsurface- Heat energy does not get conducted to higher altitudes very well- OK = -273.15°C= -459.67°F emperature is between 2.7K- Absorbs all radiation- Water Vapor- Must booses Heat Energy Get Transferred?- Even in interstellar space, the temperature is between 2.7K- Absorb and Emission- Carbon Dioxide- Convectionof energy emitted from every wavelength- If an object absorbs radiation emission, object heats up emission, object cools down square meter of an object is square meter of an object is in Watts per encouction- Average temperature of the same- Moving heat energy vertically and horizontallif- E=ox T ⁴ (results is in Watts per square meter, Wm2 or W m^2 ature- Radiation Per with What Else Happens to radiation When it Enters the absorbion- Withoat Que opF- Advection - horizontal air motions- Temperature has to be in keivins- Selective Absorbers- Tadiation passing through air molecules are picky about absorb- Transmission- Radiation (Electromagnetic in a vacuum- O is constant variable- Selective Absorbers- Atmosphere?- Advection - horizontal air motions- Temperature has to be in keivins- Selective Absorbers- Atmosphere- Advaction - Radiation (Electromagnetic in a vacuum- Objects emit more radiation-	conduction	- Facts	absorber and perfect emitter of	outgoing radiation and then
heatedALL wavelengthsstrikes it and then emits max## Main Greenhouse Gases- Heat energy does not get conducted to higher altitudes- OK = -273.15°C = -459.67°Fpossible radiation- Water Vaporconducted to higher altitudes- Even in interstellar space, the temperature is between 2.7K- Absorption and Emission- Carbon Dioxidevery welltemperature is between 2.7K- If an object absorbs radiation, it must also emit radiation- Nitrous OxideTransferred?- Total Radiation emitted = Sum of energy emitted from every- If absorption is greater than emission, object heats up emission, object heats up- Ozone- Heat transferred due to the movement of a substance from one place to another- Total Energy emitted by every square meter of an object is square meter of an object is- If absorption = emission, object's temperature remains the same- Without greenhouse gases, it would be 0°F- Much more efficient than conductionEav Law square meter, Wim2 or W m^-2- Radiative Equilibrium Temper- ature## What Else Happens to Radiation Passing through air motions, also called thermals- Temperature has to be in which type of radiation they will- Radiation passing through air molecules without interacting- Radiation (Electromagnetic radiation (Electromagnetic radiation eradiation- ois constant variable- Selective Absorberswith any of them- Radiation (Electromagnetic radiation is ransmitted- Nere sine wavelength- Some will only eat shortwave radiation- About 55% of incoming solar radiation- Temperature has to be in <td>- Ground absorbs sunlight</td> <td>- All objects above Absolute</td> <td>radiation</td> <td>reemit some of it back to the</td>	- Ground absorbs sunlight	- All objects above Absolute	radiation	reemit some of it back to the
- Heat energy does not get conducted to higher altitudes very well- OK = -273.15°C= -459.67°F - Even in interstellar space, the 	- Air in contact with ground gets	Zero radiate (emit) energy at	- Absorbs all radiation that	surface
conducted to higher altitudes- Even in interstellar space, the temperature is between 2.7K- Absorption and Emission- Carbon Dioxide## How Does Heat Energy Getand 5Kmust also emit radiation- Nitrous OxideTransferred?- Total Radiation emitted = Sum of energy emitted from every- If absorption is greater than emission, object heats up- Ozone- Convectionof energy emitted from every- If absorption is less thanEffect- Movement of a substance from one place to another- Total Energy emitted by every- If absorption is less thanEffect- Much more efficient than conductiongiven by the Stefan-Boltzmann square meter of an object is in Watts per square meter, W/m2 or W m^-2- Radiative Equilibrium Temper- ature- Without greenhouse gases, it would be 0°F- Convection - vertical air motions, also called thermals- Watts=Joules per second, J/s or Js^-1- Absorption- Transmission- Advection - horizontal air motions- Temperature has to be in Kelvins- Absorption- Radiation they will absorb- Radiation passing through air molecules with any of them- Radiation or Radiation Energy- Hot objects emit more radiation than cooler objects- Selective Absorbers- About 55% of incoming solar radiation is transmitted- The only heat transfer possible- There is one wavelength than cooler objects- Sone will only eat shortwave radiation- About 55% of incoming solar radiation- Can also transfer heat in air or water(A_max) that an object will emit most of its radiation- Shortwave is less	heated	ALL wavelengths	strikes it and then emits max	## Main Greenhouse Gases
very welltemperature is between 2.7K- If an object absorbs radiation, it- Methane## How Does Heat Energy Getand 5Kmust also emit radiation- Nitrous OxideTransferred?- Total Radiation emitted = Sum- If absorption is greater than- Ozone- Convectionof energy emitted from everyemission, object heats up### Benefit of the Greenhouse- Heat transferred due to thewavelength- If absorption is less thanEffectmovement of a substance from- Total Energy emitted by everyemission, object cools down- Average temperature of theone place to anothersquare meter of an object is- If absorption = emission,- Without greenhouse gases, itowning heat energy verticallyE = x T ⁴ (results is in Watts per- Radiative Equilibrium Temper-## What Else Happens toand horizontal with the convection - vertical air- Watts=Joules per second, J/s- Absorption- Transmission- Advection - horizontal it- Temperature has to be inwhich type of radiation they will- Radiation passing through air- Radiation (Electromagnetic- o is constant variable- Selective Absorberswith any of them- The only heat transfer possible- horizone objects- Shortwave is less than 1.4 µm- Reflection- Can also transfer heat in air or(A_max) that an object will emit- Some will only eat longwave- Radiation that bounces off an object s temperature is less than 1.4 µm	- Heat energy does not get	- 0K = -273.15°C= -459.67°F	possible radiation	- Water Vapor
## How Does Heat Energy Get Transferred?and 5Kmust also emit radiation- Nitrous OxideTransferred?- Total Radiation emitted = Sum of energy emitted from every wavelength- If absorption is greater than emission, object heats up- Ozone- Heat transferred due to the movement of a substance from one place to another- Total Energy emitted by every square meter of an object is given by the Stefan-Boltzmann- If absorption is less thanEffect- Much more efficient than conductiongiven by the Stefan-Boltzmann square meter, W/m2 or W m^-2- Mithout greenhouse gases, it would be 0°F- Without greenhouse gases, it would be 0°F- Moving heat energy vertically and horizontally- E=o x T ⁴ (results is in Watts per square meter, W/m2 or W m^-2- Radiative Equilibrium Temper- ature## What Else Happens to Radiation ther tenters the Atmosphere?- Convection - vertical air motions, also called thermals - Advection - horizontal airor Js^-1- Gas molecules are picky about which type of radiation they will absorb- Transmission- Radiation (Electromagnetic radiation or Radiant Energy)- Not objects emit more radiation than cooler objects- Selective Absorberswith any of them- The only heat transfer possible in a vacuum- There is one wavelength (A_max) that an object will emit most of its radiation- Shortwave is less than 1.4µm - Seme will only eat longwave radiation that bounces off an object at the same angle object,	conducted to higher altitudes	- Even in interstellar space, the	- Absorption and Emission	- Carbon Dioxide
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- Can also transfer heat in air or water Most of its radiation will emit most of its radiation fits radiatis radiation fits radiation fits radiation fits r	- The only heat transfer possible	than cooler objects	radiation	radiation is transmitted
water most of its radiation radiation object at the same angle object,	in a vacuum	- There is one wavelength	- Shortwave is less than 1.4µm	- Reflection
	- Can also transfer heat in air or	(λ_{max}) that an object will emit	- Some will only eat longwave	- Radiation that bounces off an
- Wien's Displacement Law and it leaves at the same	water	most of its radiation	radiation	object at the same angle object,
		- Wien's Displacement Law		and it leaves at the same

С

By chanhmuoi

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intensity

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Chapter	2 (con	t)
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- Scattering

- Produces a large number of rays traveling in all different directions

- Scattered radiation is weaker than what originally hit the object - Gasses scatter solar radiation preferentially

- Some wavelengths are scattered better

- Atmospheric gases - mostly N2 and O2 scatter blue/violet more effectively than reds/oranges

- Violet is scattered best

- Blue is at higher intensity level than violet

- Human eye detects blue better than violet

- When Sun is on horizon, light travels through a lot more atmosphere than when Sun is overhead

Quantifying Reflected Radiation

- Albedo

- Percentage of radiation

reflected by an object

- Average albedo for Earth is about 30 percent

- Average albedo for the Moon is about 7 to 12 percent

- A perfect reflector would have an albedo of 100%

- Saturn's moon Enceladus has an albedo of almost 100% ## What Causes Temperature Differences?

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Chapter 2 (cont)	Chapter 2 (cont)	Chapter 2 (cont)
 Solar Radiation Intensity largely determines temperature High solar radiation intensity- tropical areas Low solar radiation intensity = arctic/antarctic area Solar Radiation Intensity = Power/Area Partly determined by height of Sun above horizon Midday sun always high in the 	 Vernal (spring) equinox: March 21 or 22 Vertical rays at the equator 12 hour days/nights everywhere ## Solar Noon The time when the sun reaches its highest point in the sky halfway between sunrise and sunset 	 Sun will be at it lowest point in th noon on the first ## Procedure to Solar Noon Ang 1. Where is the s ation Calculate latit the SD Subtract this of between 90°
sky in the Tropics	## Solar Declination	
- Midday sun never high in the	- The latitude where Sun is	Chapter 3
sky in Arctic/Antarctic areas ## Important Dates to Remember - Solstices and Equinoxes - Summer solstice: June 21 or 22 - At solar noon, sun's rays are vertical at Tropic of Cancer 23 1/2° N Latitude - Longest day - WInter solstice: December 21 or 22 - Vertical rays at Tropic of Capricorn: 23 1/2°S Latitude - Shortest day	directly overhead at solar noon - Can only be in the tropics on any given day ## Solar Elevation Angle (SEA) - Angle the Sun makes with horizon at any time - When sun is on horizon, SEA is 0° - Halfway up into the sky, the SEA is 45° - If sun is directly overhead, SEA is 90° ## Solar Noon Angle (SNA) - Angle the Sun makes with the horizon at solar noon	## Temperature - Daily Mean - Average of the mperature readin - Add high low two - Daily Temperat - Difference betw low - Monthly Mean - Average of dail month - Annual Mean - Average of the means for the ye
 Autumnal equinox: September 22 or 23 Vertical rays at the equator day and night are equal 	 Sun will be at its highest point in the sky at solar noon on any given day Sun will be at absolute highest 	 Annual Tempe Difference betw and lowest month
aug and high are equal	point in the sky at solar noon on	## Controls of T Anything that de

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its absolute he sky at solar t day of winter o Finding the gle Solar Declintude difference to difference

e Definitions

e 24 hourly-te-

lings

and divide by

ature Range

ween high and

ily means for the

e 12 monthlyear

erature Range

ween highest thly mean **Femperature** Anything that determines the temperature of a location is called "Control of Temperature" - #1 Control: Amount of Solar Radiation received

the first day of summer

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Chapter 3 (cont)

- Solar Angle
- Length of daylight
- Latitude determines solar angle and day length
- Areas on same latitude have the same solar angles and number of daylight hours on any given day

temperature

Consequences of Being Next

to Large Body of Water

- So latitude is no. 1 control - Differential heating of land and
- water
- Land and water do not heat up/cool down at the same rate - Water requires 3-5x as much energy than land to heat up to
- the same temperature
- Geographic position - If prevailing winds blow from sea to land (windward coast), temperatures will not change
- much - Tend to have a small annual temperature range
- If prevailing winds blow from land to sea (leeward coast), temperatures will fluctuate much
- more - Tend to have a larger annual temperature range
- Ocean currents
- Warm Gulf Stream
- "River" of warm water

transports heat to northern latitudes

- Western Europe is much milder than it should be
- Effects of warm ocean currents - Palm Trees in England and Ireland



By chanhmuoi

Chapter 3 (cont)	Chapter 3 (cont)
- Effects of Cold/Warm Ocean	- Inland Winnipeg and Coastal
Currents	Vancouver
- Poleward currents bring	- Cities are located at a similar
warmer conditions	latitude
- Equatorward current bring	- Vancouver has a milder
cooler conditions	climate
- Another Effect of Cold Ocean	- Temperatures in S.
Currents	hemisphere do not fluctuate as
- Land is pretty dry	much
- Ex. Atacama Desert is the	- S. Hemisphere is the "water
driest place on Earth due to the	hemisphere"
cold Peru Ocean Current	- Water moderates temperature
- Elevation	## Minimum and Maximum
- Temperatures usually	Temperatures of the Day/Year
decrease with altitude in the	- Delay in reaching high temper
troposphere	ature: Lag of the Maximum
- Atmosphere is mostly transp-	- Also applies to the seasons
arent to solar radiation but the	## Urban Heat Island Effect
ground absorbs almost all	- Interior sections of cities tend
radiation that hits it	to be warmer than surrounding
- Air in contact with ground	rural areas
(conduction) heats up the most	## Temperature Measurements
- Atmosphere is heated from	- Mechanical thermometer
bottom up	- Liquid in glass expands wher
- Cloud cover	heated, contracts when cooled
- Clouds (or water vapor) lower	- Maximum thermometer -
surface temperatures during the	mercury
day	- Minimum thermometer -
- Clouds (or water vapor)	alcohol
increase surface temperatures	- Thermograph
at night	- Two metals in the strip will
- Albedo variations	expand/contract differently
- High albedo reduces surface	depending on the temperature
temperature	
- Low albedo increases surface	

Chapter 3 (cont)

- Electrical thermometers
- Thermistor measures the
- resistance to electric current
- Provides accurate temperature reading even when temperature

changes quickly (radiosondes)

- Louvered sides (slits in the

- Over grass and away from

- 1/5m (5 feet) above ground ## Crop Protection Against the

- Frost/Freeze Prevention

to mix warm and cool air

the water freezes

- Water sprinklers add heat from

- Air mixing uses wind machines

- Orchard heaters produce the

most successful results, but fuel

cost and pollution can be signif-

Heat Stress and Wind Chill: Indices of Human Discomfort

- Heat Stress Index: Temperature the body perceives when

you include effects of humidity

reduced when humidity is high

- Evaporation of sweat is

the latent heat of fusion when

- Instrument shelters

- White box

housing unit)

buildings

Cold

icant

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Chapter 3 (cont)

Apparent Temperature:
temperature a person perceives
Wind Chill Index: Temperature
the body perceives when you
include effects of wind

- Cold, dry air will evaporate moisture from the body

 Wind will blow away isolating air layer that surrounds the body
 ## Temperature and the Economy

Heating Degree Days
Gives a sense of how often one needs to heat a building
Assumption: Heating not required when daily mean temperature is ≥65°F, then there is zero heating degree days
For each degree the mean temperature < 65°F, this is counted as one Heating Degree Day

- Cooling Degree Days

- Cooling not required when daily mean temperature is 65°F or lower

 Each degree of temperature > 65°F is counted as one Cooling Degree Day

- Heating/Cooling Degree Days and Electric Bills

- Heating bill correlates with heating degree days

- Growing Degree Days

Chapter 3 (cont) Chapter 4 (cont) - A way to determine if a crop - When it's warmer, \$H_2O\$ can be successfully grown in molecules break bonds temporany given area arily - Assumes a BASE temperature - Flow over each other but for any given crop remain connected, liquid water - If daily mean is below the - Higher kinetic energy state base, the plant goes dormant ### Water Vapor - The difference between this - When it's very warm, \$H_2O\$ BASE temperature and the daily molecules break bonds mean temperature is a Growing completely - Molecules scatter in random Degree Day - Some crops go dormant if daily directions, gaseous water = mean is too high water vapor - If daily mean > 86°F, many - Highest kinetic energy state plants stress out, go dormant ### Ice-Water-Water Vapor - In this event, the number of - When water absorbs or GDD is set at zero releases internal energy, it can change phase Chapter 4 ## Heat Energy One calorie of heat energy is ## Water: A Unique Substance required to raise 1 gram of water ### Hydrogen Bonding 1°C - The attractive force between ## Water: Changing Phases \$H 2O\$ molecules - Latent Heat of Melting: 80 - Hydrogen side of \$H_2O\$ is calories "+" charged | Oxygen side is "-" - 80 calories of heat absorbed charged by 1g of ice melts into 1g of - + Hydrogen side attracted to water oxygen side of other \$H_2O\$ - No temperature change in the molecules ice, but surrounding air gets ### Formation of Ice colder - When it's cold, \$H_2O\$ - Latent Heat of Fusion: 80 molecules cannot break their calories

- 80 calories of heat released by
1g of liquid water freezes to 1g
of ice

Chapter 4 (cont)

- No temperature change in the water but surrounding air does heat up

- Latent Heat of Vaporization:

between 540 and 600 calories - 540 to 600 calories absorbed

by 1g of liquid water evaporate to 1g water vapor

- Heat is taken from surrounding air resulting in decrease air temperature

- Latent Heat of Condensation: between 540 and 600 calories

- 540 to 600 calories released by
 1g water vapor condenses to 1g
 liquid water

- Heat is added to the surrounding air resulting in a temperature increase

- Latent Heat of Sublimation: about 680 calories

- 680 calories of heat absorbed by 1g of ice to sublime to 1g of water vapor

- Heat removed from surrounding air greatly cools the air around the ice

- Latent Heat of Deposition: about 680 calories

about 680 calories

- 680 calories of heat released
 by 1g of water vapor deposits to
 1g of ice

- Heat added to the environment greatly warms the air around the ice

By chanhmuoi

bonds

structure, ice

Liquid Water

- Remain fixed in a crystalline

- Lowest kinetic energy state

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Chapter 4 (cont)	Chapter 4 (cont)	Chapter 4 (cont)	Chapter 4 (cont)
## Measuring Water Vapor	- When air is saturated, conden-	- Amount of water vapor allowed	- There usually needs to be
- Mixing Ratio	sation occurs	in air is mostly determined by	condensation nuclei for it to form
- Mass of water vapor/mass of	- The lower the RH, the faster	temperature	- Dust, smoke, ash, salt, sulfate
dry air it is in	water evaporates	- Warmer temperatures allow for	particles, and even bacteria
- Water vapor measured in	- Watering lawn in the morning	more water vapor	- Without these, clouds would
grams	is more effective than watering	## When Air is Saturated	not form and RH would need to
- Dry air measured in kg	in the afternoon	Some kind of Condensation	be greater than 100% to form
- Actual mass of water vapor in	- RH can be over 100% but not	(Deposition) Occurs	- Deposition can occur in bitterly
the air	for long (supersaturation)	- Dew forms	cold air without nuclei
- Saturation Mixing Ratio	- Violent updrafts in thunde-	- Frost forms (if below freezing)	- Condensation or deposition will
- Max amount of water vapor	rstorms can supersaturate	- Fog forms	always occur when RH reaches
allowed in the air (mostly	- Dew Point Temperature (Td)	- Cloud forms	100% (in this class)
determined by temperature)	- Temperature at which	## Formation of Dew	### Fog
- Vapor Pressure	saturation occurs	Ideal Conditions	- Cloud with base at the ground
- Pressure exerted by water	- Better way of measuring actual	- Clear skies, light winds	- Forms when air temperature =
vapor	water vapor content	- Allows for maximum radiat-	dew temperature
- Total air pressure = sum of	- Absolute Humidity	ional cooling of the ground	- 4 types
pressure from each gas	- Specific Humidity	- Air in contact with ground cools	1. Radiation
- The more water vapor in the	### Relationship Between T, Td,	to the dew point	1. Ground cools rapidly and
air, the greater its contribution to	and RH	- If air continues to cool below	causes saturation near the
the total air pressure	- When T and Td are close, RH	freezing, frozen dew occurs	ground
- Relative Humidity	is high	## Formation of Frost	2. Nocturnal inversion can
- Mass of water vapor/mass of	- When T and Td are far apart,	When Deposition occurs instead	prevent higher fog
water vapor allowed to be in the	RH is low	of condensation	3. Clear skies, light winds, high
air	### Water Vapor Rule	## Clouds	relative humidity
- RH=mixing ratio/saturation	- Air can only hold so much	Bringing Air to Saturation	4. Also called Valley frog
mixing ratio	water vapor	- Cooling air is the easiest way	2. Advection
- RH=vapor pressure/saturation	- When it has as much water	to saturate the air	1. Warm, moist air blowing
vapor pressure	vapor as physics allow, we say	- Air always cools as it rises	horizontally(advecting) over a
- Relative humidity can be	the air is saturated	### Formation of Clouds	"cold" surface
misleading	## Saturation Vapor Pressure	- Clouds result from conden-	3. Upslope
- Does not tell you how much	- Pressure exerted by water	sation and/or deposition	1. Humid air moves up a hill or
water vapor is in the air unless	vapor when the air is saturated		mountain
you know the temperature of the	with it		

- Does not tell you ho water vapor is in the you know the temperature of the air

- RH does tell you how close you are to saturating the air



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Chapter 4 (cont)

Chapter 4 (cont)

- 1. The upward flow causes the air to expand, cool, which can eventually reach 100%
- 4. Evaporative
- Process of Evaporation involved
- Rain falls, partially evaporates
- Adds water vapor to air, leads to saturationEvaporation also chills air,
- assiting in bringing air to saturation
- Precipitation Fog
- Steam Fog
- Cool dry air moves over warm surface, esp. water
- Common over lakes in autumn when lake is still warm from summer and air above it is cold and dry
- ### Classification of Clouds
- Jean-Baptiste Lamarck (1802)
- Luke Howard (1803)
- Abercromby and Hildebrandsson (1887)
- Clouds are classified by appearance, shape, and how high they are.
- High Clouds
- Cirrus Clouds
- Composed mostly of ice
- crystals
- Thin due to limited water vapor
- Cirrocumulus
- Composed of mostly ice
- crystals but with lumps
- Cirrostratus



Chapter 4 (cont)

- Composed of mostly ice - Rising air below clouds, crystals and when thin, often sinking air between clouds causes a halo around sun/moon - Cumulus Humilis - Can be thicker but usually, sun - Fair weather clouds still partially shines through - Humble clouds that do not Middle Clouds threaten to build into storms - Altocumulus - Cumulus Congestus - Mostly water droplets - May develop into thunde-- Darker regions noted rstorms - Can signal the possibility of - Cumulonimbus afternoon storms - Most intense rainmaker - Altostratus - Overshooting top - Mostly water droplets with a - When the cloud punches "frosted glass" sun appearance through the stratosphere - Usually does not permit Special Latin Descriptive Terms shadows to be cast - Cloud Varieties Low Clouds - Uncinus - Stratus - Hooked shaped, often appear - Layer of low clouds covering before stormy weather moves in the skv - Cirrus uncinus - Often seen after fog "lifts" - Fractus - Can have mist or drizzle - Stratus or cumulus clouds that - Nimbostratus appear broken - Light to moderate rain or snow - Cumulus fractus better known - Stratocumulus as scud clouds - Lumpy clouds that appear in - Mammatus rows with some separation - Udder-shaped protuberances - Lower than altocumulus with often associated with the underside of a cumulonimbus larger cloud elements Clouds of Vertical Development anvil cloud - Cumulus - Only cloud that forms in - Cauliflower or cotton ball sinking air clouds **Unusual Clouds** - Lentiular - Lens-shaped and common over mountains and downwind of high terrain
 - Pileus
 - Cap clouds

Chapter 4 (cont)

- Form when moist air is pushed up under a develeoping cumulus cloud
- Banner Cloud
- Forms downwind of an isolated mountain peak
- Asperitas Clouds
- Often forming near precipita-
- tion-bearing clouds
- Undulating up and down like ocean waves
- *Super-high Clouds*
- Nacreous
- Stratophere
- Noctilucent
- Mesosphere
- Reminder: Rising air cools, temperature drops to dew point, condenses
- Excess water vapor condenses into tiny droplets
- Excess water vapor used up very quickly
- This results in Billions of teeny tiny water droplets whose radii are 20 microns or less
 ## Observing Clouds from
- Spage
- Polar orbiting satellite
- Geostationary satellite
- Infrared imagery provides extra detail
- Darker shades of grey indicate warm clouds, thus low altitude
- Brighter grays and whites
- indicate cold clouds thus high altitude
- ## Water Vapor Imagery

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Chapter 4 (cont)

- Shows air motions (wind) even in cloud-free areas

- Detects water vapor at the

6.9µm wavelength

- Colorized to differentiate

between dry and moist air

Two Main Types of Nuclei - Condensation Nuclei

- Hygroscopic (water-seeking) nuclei

- Most effective condensation nuclei

- Salt crystals are the best

- Only RH ~75% required

- Hydrophobic (water-repelling) nuclei

- Least effective condensatioin nuclei

- Waxes and oil droplets

discourage but do not totally prevent condensation

- RH must be 100% or even temporarily higher

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